THE DECISION SCIENCES LABORATORY PROGRAM OF TECHNIQUES
AND FACILITIES FOR AUTOMATING RESEARCH

TECHNICAL DOCUMENTARY REPORT NO. ESD-TDR-64-553

SEPTEMBER 1964

Emir H. Shuford, Jr.

DECISION SCIENCES LABORATORY
ELECTRONIC SYSTEMS DIVISION
AIR FORCE SYSTEMS COMMAND
UNITED STATES AIR FORCE
L. G. Hanscom Field, Bedford, Massachusetts

Project 4690, Task 469003

AD 608421

DDC AVAILABILITY NOTICES

THE DECISION SCIENCES LABORATORY PROGRAM OF TECHNIQUES
AND FACILITIES FOR AUTOMATING RESEARCH

TECHNICAL DOCUMENTARY REPORT NO. ESD-TDR-64-553

SEPTEMBER 1964

Emir H. Shuford, Jr.

DECISION SCIENCES LABORATORY
ELECTRONIC SYSTEMS DIVISION
AIR FORCE SYSTEMS COMMAND
UNITED STATES AIR FORCE
L. G. Hanscom Field, Bedford, Massachusetts

Project 4690, Task 469003
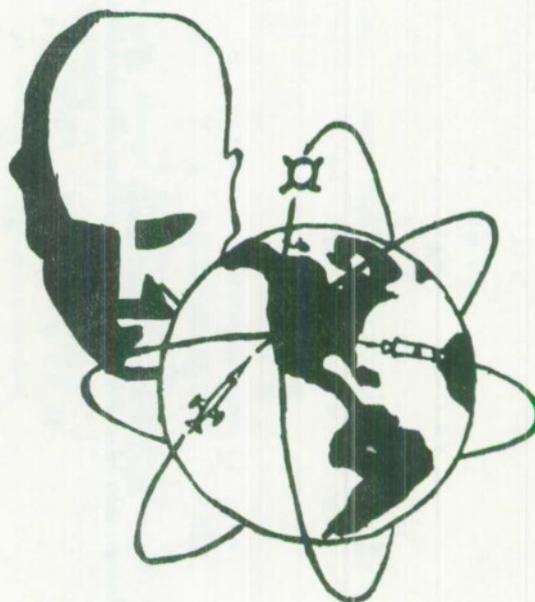
FOREWORD

The author wishes to express his appreciation to Dr. C. R. Brown, Dr. D. W. Connolly, Mr. J. S. Duva, Lt./Col. A. G. Rodriquez, and Maj. F. J. Sulkowski for invaluable advice and encouragement and to J. D. Baker, J. B. Goodenough, R. S. Nickerson, and J. R. Schjelderup for providing information used in the preparation of this report.

ABSTRACT

This is a report on the application of techniques and the use of computer facilities in automating research in the Decision Sciences Laboratory. Applications are divided into six categories; (1) real-time control of experimental tasks performed by human subjects, (2) statistical analysis of experimental data, (3) stimulation and sensitivity analyses, (4) studies in information retrieval, (5) techniques for improving the man/computer interface, and (6) computer-based personnel selection, classification, training, and proficiency testing. Examples are given of each application.

There is also included detailed facility lay-out and description of equipment characteristics.

PUBLICATION REVIEW AND APPROVAL

This Technical Documentary Report has been reviewed and is approved

DONALD W. CONNOLLY
Acting Chief, Decision Techniques Division
Decision Sciences Laboratory

ROY MORGAN, Col, USAF
Director
Decision Sciences Laboratory

- iii -

TABLE OF CONTENTS

THE DECISION SCIENCES LABORATORY PROGRAM OF TECHNIQUES

AND FACILITIES FOR AUTOMATING RESEARCH

1. Mission and Scope of Laboratory

The Decision Sciences Laboratory is an Air Force research laboratory
with a staff of approximately fifty military and civilian personnel including
mathematicians, behavioral scientists, engineers, and computer programmers.
As part of the Deputy for Engineering and Technology of the Electronic
Systems Division, AFSC, the Laboratory is

> "Responsible for the planning, development, procurement
> and management of assigned display subsystems in support of
> System Program Directors. Provides engineering services as
> requested to all ESD elements on display, human performance
> and man/machine problems for both current and future Command
> and Control needs. Formulates exploratory development require-
> ments; initiates or causes the initiation of appropriate
> exploratory development programs. Manages and/or conducts
> appropriate exploratory development, advanced development and
> operational support programs in display, human performance
> and man/machine problems. Responsible for monitoring approp-
> riate related MITRE and Lincoln Laboratory activity."

In order to better accomplish these mission responsibilities, the
Decision Sciences Laboratory acquired a computer in October of 1961. As
a result of continuing experience based on improving the articulation between
the operation of the computer system and the other operations and functions
of this Laboratory, the original computer installation has evolved into the
configuration shown in Appendix I.

This computer system is being utilized currently at a rate of approximately
15 hours per day (5 day week) for (a) the real-time control of experimental
tasks performed by human subjects, (b) the statistical analysis of the data of
these experiments, (c) the conduct of simulation and sensitivity analysis studies
based on formal mathematical models of complex systems, (d) the preparation,

editing, and analysis of textual material used as the data-base in an exploration of properties of information retrieval systems, (e) the preliminary development and evaluation of a variety of techniques designed to improve the man/computer interface, and (f) studies in computer-based personnel selection, classification, training, and proficiency testing. These activities will be discussed in some detail.

2. Real-Time Control of Experimental Tasks Performed by Human Subjects

General discussions of the use of the Decision Sciences Laboratory computer as a control device in psychological experimentation may be found in Brown, Hayes, and Sumby (1962) and in Nickerson (1964a). A particular example is provided by a program of research on temporal limitations of simple decision processes which is currently underway. In this case, the computer has been programmed to schedule the presentation of signals in accordance with the objectives of individual experiments, to present signals on an oscilloscope, to measure subject's response times, and to produce a punched paper tape trial-by-trial record of each experimental run (Nickerson, 1964b). A second example of the use of the computer itself as the control instrument for automated data collection is an ongoing series of experiments dealing with the temporal characteristics of human information storage and retrieval (Nickerson, 1964c).

Both of these applications represent a considerable advance in experimental methodology. The programs provide the experimenter with easy control over a wide variety of experimental variables allowing a series of related experiments which would be difficult, if not impossible, to implement with any single configuration of more conventional apparatus. An average of about two hours per day for the last six months has been devoted to data collection under these two research programs.

- 2 -

Another example is provided by a study (Baker & Goldstein, 1964) of

an information retrieval task based on a retrieval tree with branches of

differing lengths. Man/computer communication was through computer-driven

scope and light pen. The computer maintained a record of the subject's

performance in order to determine what information the subject was to retrieve

next and when the subject had reached the learning criterion and thus terminate

the experiment.

In some cases in which it has not been practical to use the computer

facility to actually control the data collection session, it has been possible

to use it to advantage in both the generation of stimulus schedules and the

analysis of data. For example, in one case, an automated facility was designed

for experimentation in the area of signal detection. By providing the control

equipments with paper tape reader and punch, a functional link was established

between the special purpose equipment and the PDP-1. Thus, a signal schedule

produced by the computer could be read by the control equipment and the paper

tape output of the latter could be read and analyzed by the computer. The

need for time consuming manual signal sequencing and data transcription was

eliminated. This facility has been described by Watkins, Nickerson, and

Schjelderup (1964) while the results of the first experiment in which it has

been used have been described by McGoldrick, Nickerson, and Watkins (1964).

In summary, the Decision Sciences Laboratory has found that after a

considerable initial investment in learning computer programming and operation,

the computer facility can be used to improve both the quality and efficiency of

experimentation by scientists in the Laboratory. In fact, in some cases, the

marginal cost of experimentation has been so reduced as to result in an

embarrassment of riches. In some areas of research it is quite feasible to

- 3 -

collect and analyze the data of an experiment at the rate of one every one or two weeks. Under ordinary conditions, each experiment would be reported in a separate journal article. Data collection and analysis would require several months while writing the journal article might require several more weeks or months. Under these new automated conditions, however, the experiment requires a week, say, while writing the report of the experiment still requires several weeks or months. One is tempted to wish that the reporting process might be similarly automated.

Continuing with this line of thought, suppose that computers come into widespread use for the real-time control of experiments in the behavioral sciences. This will result in a vast increase in the potential rate of experimentation. If, under these conditions, experiments are conceptualized and reported in the same manner as before, a great number of additional experimental reports will be available for publication. If these additional reports are published along with the normally occurring reports then the "information explosion" will be further exacerbated. If the number of published reports is held under control then a larger percentage of experimental findings will never see the light of day in published form. In either case, a degradation in the relative value of experimental findings is likely to result. Thus, by making experimentation cheaper the computer will reduce the value of experimentation.

What are the ways around this dilemma? Report only a long series of related experiments? Place more emphasis on theoretical developments in behavioral science? Devise more sophisticated experimental techniques

designed to yield a much greater amount of information? Whatever method

is utilized, the growth of computer-controlled experimentation is likely

to have a profound impact on the nature of behavioral science research.

Merely automating traditional laboratory procedures, though a significant

advance, may not be the final answer.

3. Statistical Analysis of Experimental Data

Data analysis is certainly a well developed area of computer application.

Until recently, data analyses conducted on the Decision Sciences Laboratory

computer have been limited to rather large and sophisticated problems

such as those described by Massengill (1964). This limitation is natural

in light of the high cost of programming the solution to a particular data

analysis problem. Now, the existence of data analysis systems such as

STATPAC, GRAPHPAPER, and "Computer-Aided Analysis of Variance" (see below)

which essentially eliminate the marginal cost of programming have made the

Decision Sciences Laboratory computer facility available for a much wider

range of data analysis tasks, particularly the smaller, less complex jobs as

illustrated in Baker (1964) and in Baker and Organist (1964).

4. Simulation and Sensitivity Analyses

This is another well developed area of computer application so just two

examples will be mentioned here. First, the Decision Sciences Laboratory

computer facility has been used to study the behavior of optimal strategies

as internal and external parameters are changed in a rather sophisticated

dynamic programming class of problems (Toda, 1963; Nakahara & Toda, 1964a,b;

Nakahara, Shuford, & Toda, 1964a,b). Second, Roby and Nickerson (1963) have

used Monte Carlo methods in a simulation of complex organizational behavior.

- 5 -

5. Studies in Information Retrieval

Statistical methods for inferring associations between words in an information retrieval corpus are based on certain assumed regularities in the corpus. An experiment designed to confirm the existence and determine the structure of these assumed regularities has been completed. A text of 60,000 words is being used as the basic data in the experiment and the various analyses required have been conducted on the Decision Sciences Laboratory computer. Because of the small size of the machine, the several sorts required in the course of processing the data each take several hours. On the other hand, the use of the scope has reduced processing time significantly in some cases.

A particular job, which involved editing each word in the experimental corpus, was done with 15 man-hours of effort using the scope, whereas the same job using standard data processing methods would have taken at least 40 man-hours to achieve the same result. In another part of the experiment, 7,500 human judgements were collected with 5 man-hours of effort (not including the subjects' time) by presenting the materials to be judged on the scope. Approximately 10 man-hours would have been required with standard methods. Extensive use has also been made of STATPAC and GRAPHPAPER in the course of analysis. A report of this experiment by Rubinstein and Goodenough is nearing completion.

6. Techniques for Improving the Man/Computer Interface

The approach underlying all of these techniques is that a man/computer interface is improved whenever the man finds that it is now easier to use a computer in his particular job than it was before and that there has been no compromise made in the quality of help provided by the computer. For

example, a computer-based aid is generally more acceptable to a potential user when (1) it does not require the learning of a special vocabulary and grammar or of mnemonic codes, (2) it provides him with on-line control of the process and essentially instantaneous feedback of computational and other results, (3) it provides automatic checks for consistency and other types of errors which it calls to the attention of the user while at the same time being error-proof itself, and (4) it is organized so that the user can learn the special techniques provided by the computer-based aid through use of the aid in performing his task.

Given sufficient improvement in the man/computer interface, two types of results should be observed. First, since the use of a computer would no longer be restricted by high programming costs, time delays, etc. to the solution of the "big" problems, the number of different types of problems solved with the aid of computers should undergo a significant increase. Second, since the use of a computer would no longer be limited to those experts who have received extensive training in special vocabulary, grammars, and techniques of operation peculiar to computers the number of people utilizing a computer in their daily work should undergo a significant increase.

The computer facility of the Decision Sciences Laboratory is run as an open shop type of operation in which programming scientists and technicians may assume complete control of the system for compilation, on-line debugging, and final running of their programs. Therefore, emphasis was placed initially on improving the man/computer interface in certain general-purpose programs designed to support this activity. Two examples are given below.

(1) SATED. SATED is a program for preparing and editing symbolic material displayed by a computer-driven scope. It is intended to

- 7 -

make optimal use of the computer-driven scope and typewriter to help the operator and applies certain principles of man/machine communication determined by trial and error at the Decision Sciences Laboratory (See Weene, 1964).

(2) SEETAPE. SEETAPE is a program for dumping magnetic tape information on the scope. The user may specify the structure of the tape block to be dumped, specify how much of the block he wants to see, and manipulate the magnetic tapes, all under typewriter control (See Goodenough, 1964a).

As a result of these and similar programming efforts, it soon became apparent that the man/computer interface could be improved (at least in some applications) to the extent that practically no knowledge of computer operation and programming need be required of a potential user. This suggested that it might be possible to make the power of the computer available to the non-programming scientists and technicians at the Decision Sciences Laboratory. This conjecture was evaluated by the development and use of the three programs described below.

(3) STATPAC. STATPAC is a lightpen-directed on-line system for the elementary statistical analysis of experimental data. The original data is entered into the computer by means of punched paper tape. The scientist, using scope and lightpen, can then perform a variety of mathematical operations on his data. Intermediate results can be displayed on the scope. Results of lasting interest are either typed or punched out at the option of the scientist (See Goodenough, 1964b).

(4) GRAPHPAPER. The GRAPHPAPER program allows a user to input, on paper tape, a set of x, y pairs to be graphed. The user can create any axes appropriate to his data, and see a linear, second, or third order least-squares fit displayed. Data points which lie outside the area specified by the axes are not displayed or used for calculating curve fits. The user can expand to "full scale" any rectangular subportion of the graph.

Input data tapes are compatible with STATPAC, and eventually the two programs will be integrated. Display techniques are used which reduce to a low amount the prior knowledge required to use the system (see Goodenough, 1964c).

(5) Computer-Aided Analysis of Variance. The primary motivation for developing a user-computer system for the analysis of variance (AV) technique is to associate variance quantities with graphic representations of data. Certain quantities, such as an interaction variance, are relatively meaningless unless the graphic correlate is appreciated. Researchers who are quite familiar with the computational procedures associated with AV may only partially understand the meaning of AV quantities. Thus the AV program is designed to have both the properties of a tool and of a teaching device.

Primary communication between the user and the program is thru a CRT type scope and associated lightpen. To illustrate the main feature of the AV program, assume that a variance partition has been requested and that the region of the scope reserved for answers displays the following:

$$V(y:A,B) = V(y:A) + V(y:B/A)$$

$$294.5 = 87.2 + 207.3$$

If the user wishes to see the graph implied by one of the terms, he points the lightpen at it and the operator "graph" from the operator list. Thus, he may generate the command

GRAPH $[V(y:B/A)]$

If he is satisfied with the current command he points the lightpen at EXECUTE and the appropriate graph is generated and displayed. A similar procedure allows the user to go from a graph to a variance term.

Other features allow the user to:

1) change the "hard copy" format of the data.

2) check for homogeneity of variance.

3) transform the data.

4) make photographs of analyses, graphs, or matrices under computer control.

Some users have estimated that they have saved several weeks work by using this program on one problem.

These programs, though still undergoing continual modification and improvement, have been very well received by users. Thus, it appears that in those instances where the potential user is already quite familiar with the computer-aided technique, i.e., elementary statistical analysis of data, graphical representation of empirical and theoretical relations, and analysis of variance estimation and testing procedures, methods can be developed which make the computer immediately accessible and acceptable to a non-programming user. This confirmation led to the further conjecture that methods could be

- 10 -

developed that introduce, train, and aid a non-programming user in analytic and synthetic mathematical procedures which represent the most advanced state of the art in their areas and, thus, are probably quite unfamiliar to the user. The two programs described below are designed to test this conjecture.

(6) Information-Theoretic Analysis of Structure. The statistical and mathematical tools which are available to the scientist are inadequate for uncovering the structure that exists among many variables. Current techniques impose strong limitations. For example, measurement variables must be metric, or only one dependent variable is allowed, or only two sets of variables can be handled. The technique under development places no metric requirements, permits any number of variables, and allows for any number of sets of variables. The environment, task, and the observer's history and behavior may be dealt with in the same framework.

The calculations necessary for information-theoretic analysis of structure require a computer. A user-computer system is necessary because decisions must be made which involve knowing the meaning of the variables. A preliminary study compared this technique to a classical technique. Several months of analysis time were reduced to a few hours.

A result of computer-based information-theoretic analysis of structure will be a much closer tie between experiment and application. It allows experiments to have the same degree of complexity as the domain of application. Similarly, theory may deal with interrelation-ships among systems of variables.

- 11 -

(7) CORTEX. This is a computer-based system for aiding decision

making in almost all operational settings such as management,

logistics, procurement, engineering design, research, weather

forecasting, and intelligence. This wide scope of application is

achieved by using a computer, lightpen, and scope to make the concepts

and algorithms of mathematical decision theory available to an

individual decision maker with no knowledge of computer programming

and operation and with a minimal prior knowledge of formal procedures

for decision making. CORTEX assists the decision maker in (a) formulating

his problem, (b) assessing the probabilities, utilities, and costs

of information, (c) evaluating the expected utilities of alternative

courses of action, and (d) evaluating the advisability of gathering

additional information before making a final decision. In addition

to finding the optimal course of action implied by his formulation

of the decision problem, the decision maker can perform sensitivity

analyses in order to better understand the logical nature of his

problem and the criticality of his assumptions (See Shuford, 1964).

These two programs represent the beginning of a long-term research effort

of the Decision Sciences Laboratory aimed at determining the feasibility of

improving the man/computer interface so as to make possible the introduction

of computers to new areas of application and to large groups of new users.

The results of this in-house research effort depend in part upon the capabilities

and limitations of the Decision Sciences Laboratory computing facility.

Experience with the development and operation of these programs has

shown that the computer system illustrated in Appendix I and described in

- 12 -

Appendix II is quite adequate in all respects but one, computational power.
For example, at that stage in GRAPHPAPER at which the user requests a least-
squares fit to the displayed data, the computer stops maintaining the scope
display and devotes quite some time to computing the best-fitting function.
Then the graph reappears and the user requests to see one of the three fitted
functions. It sometimes happens that users, when conducting a series of
interrelated analyses, complain about the disappearance of the display and
about the time delay in seeing the fitted curves. It seems that this delay
in feedback can destroy a user's train of thought. The program could be
modified to maintain the display throughout the computational period but
only at a large increase in time to solution and an added investment in
programming costs and memory requirements.

These waiting times, and the consequent possibility of user dissatis-
faction if not the utter breakdown and confusion of his reasoning process,
tend to increase through the more complex data analysis programs such
as (5) and (6) up to CORTEX which sometimes involves the most extensive
computations of all. For example, CORTEX provides a set of algorithms
for the sequential gathering and evaluation of information prior to making
a final decision. One of the simpler of these algorithms has required up
to thirty-six minutes for the solution of one problem and in theory,
depending upon the particular aspects of the problem and limited by memory
capacity of the present system, could require several hours of computing
time. The displays providing for man/computer communication are, of course,
not maintained during this computing interval so the computer can devote full
time to numerical analysis of the problem.

Clearly, in order for these programmed man/computer techniques to succeed

- 13 -

they must not frustrate the user by long delays in the feedback of computational results and by interruption of the displays and, at the same time, they must provide the user with an acceptably wide range of relevant techniques of assistance in performing his job. The Decision Sciences Laboratory computer system in its present configuration is limited in its ability to perform extensive and rapid computation while maintaining communication with the user. Thus, any attempt to maintain tight articulation between system operation and the user's thought processes by avoiding long delays and interruptions results in an unacceptable restriction on tne range of techniques that can be incorporated into the system under this constraint. In other words, the possibility for effective trade-off is so limited as to jeopardize the research effort aimed at improving the man/computer interface.

7. Computer-Based Personnel Selection, Classification, Training, and Proficiency Testing.

Traditional testing techniques and test theory are based upon the implicit assumption that an individual either knows the correct answer with perfect assurance or is guessing on the basis of complete uncertainty as to the correct answer. They make no provision for the existence of misinformation, i.e., confidence in the rightness of an incorrect answer, or for different degrees of confidence and uncertainty on the part of the individual. Thus, traditional techniques are not sensitive to the growth or degradation of an individual's knowledge and proficiency and are consequently limited in their efficiency of testing and training.

Techniques for measuring an individual's uncertainty recently developed by the Decision Sciences Laboratory thus promise a revolution in the efficiency and economy of computer-based education. By providing a vast increase in information about the state of an individual's knowledge, these techniques

- 14 -

make possible the utilization of the full power of the computer through dynamically tailoring the material to be learned to the individual needs of the student.

The presentation and organization of two types of instruction are envisioned. First, computer-based self-instruction in which the material to be learned is presented by the computer system. The computer constantly assesses the development of the student's knowledge and selects and organizes the material to be presented next in such a way as to maximize the efficiency of training. Second, computer-based testing-tutorial in which the material to be learned is presented through traditional means such as text books and training manuals. The function of the computer is to efficiently and rapidly assess and diagnose the student's knowledge in a wide area of learning by using these uncertainty measurement techniques and the structure of the material to dynamically test the student. The computer then gives a tutorial account and diagnosis of the student's strengths and weaknesses.

The research effort is aimed at making a serious attempt to rapidly evaluate the effectiveness of these new techniques over a broad spectrum of materials. Successful development of these techniques will, of course, have wide applicability throughout the Air Force and the Nation.

Again, the results of this in-house research effort depend in part upon the capabilities and limitations of the Decision Sciences Laboratory computing facility. Some of the uncertainty measurement techniques have been programmed and are running on the current computer facility configuration using computer-driven scopes and light pens for man/computer communication. No great difficulty is anticipated in handling the textual material to be presented to the student. The present system should be quite satisfactory in these respects. It is anticipated, however, that when decision rules are incorporated to dynamically guide the presentation of the materials

and when simultaneous but independent use of the four subject stations is considered, the central processor operating speeds may prove to be a limiting factor.

8. Summary

The Decision Sciences Laboratory computer facility has evolved over a period of three years into its present configuration. Current and planned utilization of this facility can be discussed in terms of six categories; (1) real-time control of experimental tasks performed by human subjects, (2) statistical analysis of experimental data, (3) simulation and sensitivity analyses, (4) studies in information retrieval, (5) techniques for improving the man/computer interface, and (6) computer-based personnel selection, classification, training, and proficiency testing. Examples and references have been given for each category of use.

REFERENCES

Baker, James D. Subjective probability as a measure of short-term memory.
    ESD-TDR-64-   , In press, 1964.

Baker, James D., & Goldstein, Ira Batch vs. sequential displays: effects on
    human problem solving. ESD-TDR-64-   , In press, 1964.

Baker, James D., & Organist, Walter E. Short-term memory: non-equivalence of
    query and message items. ESD-TDR-64-254, February 1964.

Brown, Charles R., Hayes, John R., & Sumby, William H. The concept of an
    automated psychological laboratory. ESD-TDR-62-191, July 1962.

Goodenough, John B. SEETAPE: a magnetic tape dump program. ALPR-64-4, 1964a.

Goodenough, John B. A lightpen-controlled program for on-line data analysis.
    ESD-TDR-64-515, August 1964b.

Goodenough, John B. GRAPHPAPER. ALPR-64-9, 1964c.

Massengill, H. Edward Purposive systems: theory and application. ESD-TDR-64-531,
    August 1964.

McGoldrick, C. Charles, Nickerson, Raymond S., & Watkins, William H. Uncertainty
    of signal mode in bi-sensory signal detection. Paper presented to the
    American Psychological Association, 9 September 1964.

Nakahara, Jun-ichi, Shuford, Emir H., Jr., & Toda, Masanao The accident prone
    fungus-eater in finite F-E games. ESD-TDR-64-   , In press, 1964a.

Nakahara, Jun-ichi, Shuford, Emir H., Jr. & Toda, Masanao The learning fungus-
    eater in game 3. ESD-TDR-64-   , In press, 1964b.

Nakahara, Jun-ichi & Toda, Masanao Optimal strategies and human behavior in
    fungus-eater game 4. ESD-TDR-64-237, February 1964a.

Nakahara, Jun-ichi & Toda, Masanao Simple discrete fungus-eater games of class III:
    the infinite coexistent v-span 2 chain game. ESD-TDR-64-   , In press, 1964b.

Nickerson, Raymond S. The computer as a control device for psychological
    experimentation. Decuscope, March 1964a.

Nickerson, Raymond S. Decision time and psychological refractory period.
    Paper presented to the American Psychological Association, 7 September 1964b.

Nickerson, Raymond S. Response times for "same"-"different" judgments.
    ESD-TDR-64-536, In press, 1964c.

Roby, Thornton J., & Nickerson, Raymond S. Steps toward computer simulation of small group behavior. Decus Proceedings, 1963.

Shuford, Emir H., Jr. CORTEX: a computer-based system for aiding decision making. Second Congress on Information Systems Sciences, Hot Springs, Va., 22-25 November 1964.

Toda, Masanao The optimal strategies in some simple fungus-eater games. ESD-TDR-63-406, July 1963.

Watkins, William H., Nickerson, Raymond S., & Schjelderup, John R. An automated facility for forced-choice signal detection experimentation. ESD-TDR-64-383, April 1964.

Weene, Paul SATED: scope aided tape editor. ALPR-64-2, 1964.

APPENDIX I

This appendix contains block diagrams, arranged by functional grouping, showing the equipment at the Decision Sciences Laboratory computer facility.
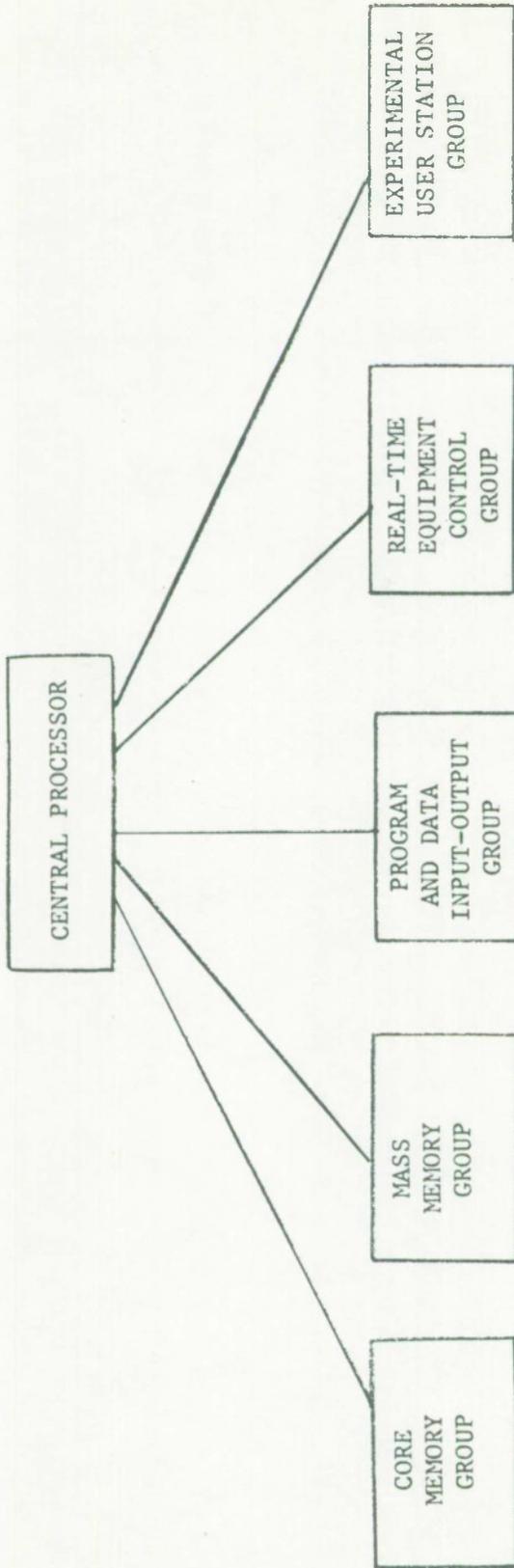
COMPUTER FACILITY ORGANIZATION
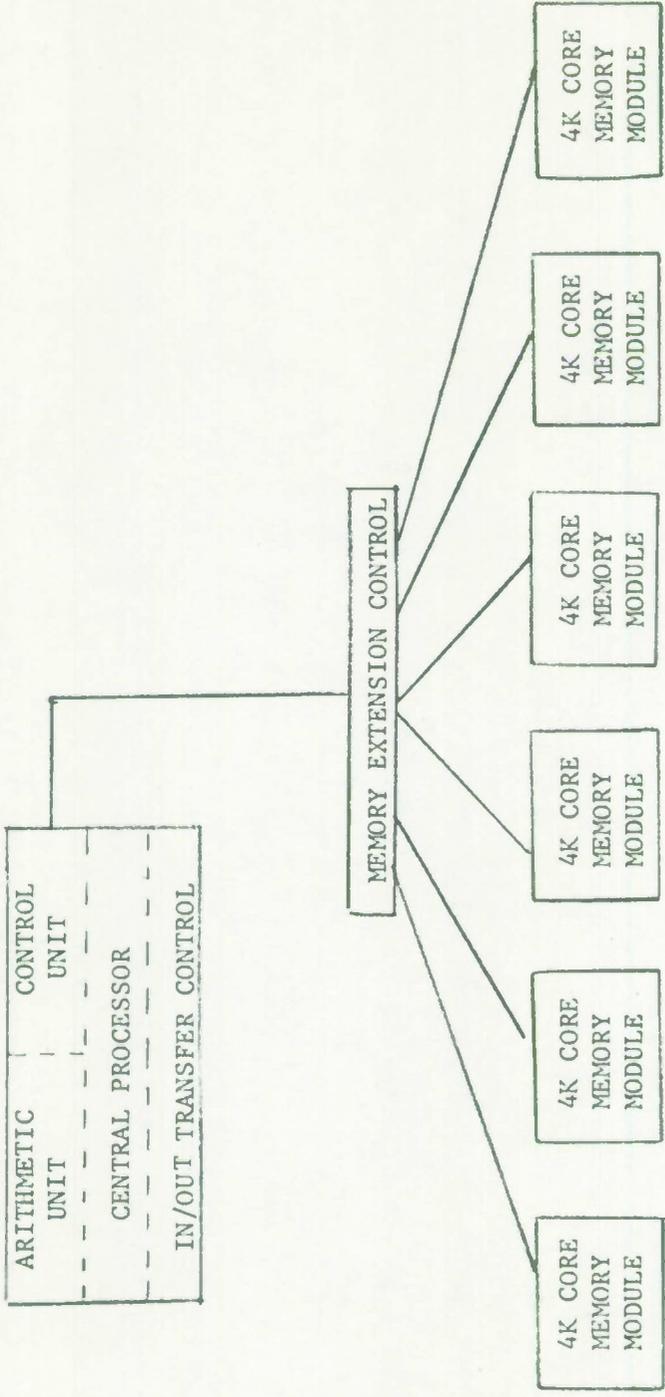
CORE MEMORY GROUP
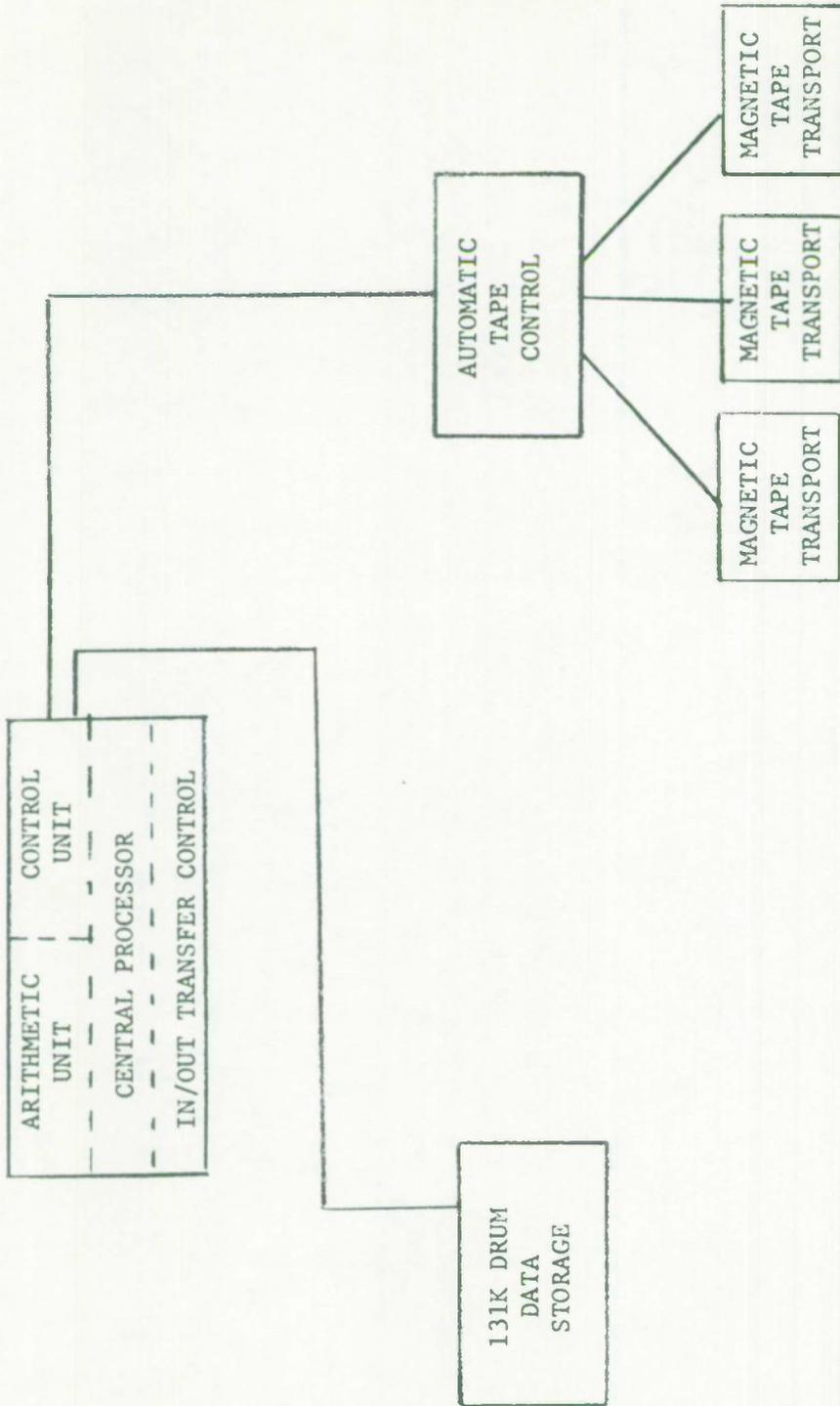
MASS MEMORY GROUP

PROGRAM AND DATA INPUT—OUTPUT GROUP

The diagram shows a block-diagram layout rotated 90 degrees:

CENTRAL PROCESSOR
- ARITHMETIC UNIT | CONTROL UNIT
- IN/OUT TRANSFER CONTROL

Connected to:
- MICROTAPE CONTROL → MICROTAPE DUAL TRANSPORT
- PAPER TAPE READER
- PAPER TAPE READER
- ALPHANUMERIC CONSOLE TYPEWRITER
- AUTOMATIC LINE PRINTER
- INCREMENTAL PLOTTER
- PRECISION CRT DISPLAY → SYMBOL GENERATOR → LIGHT PEN
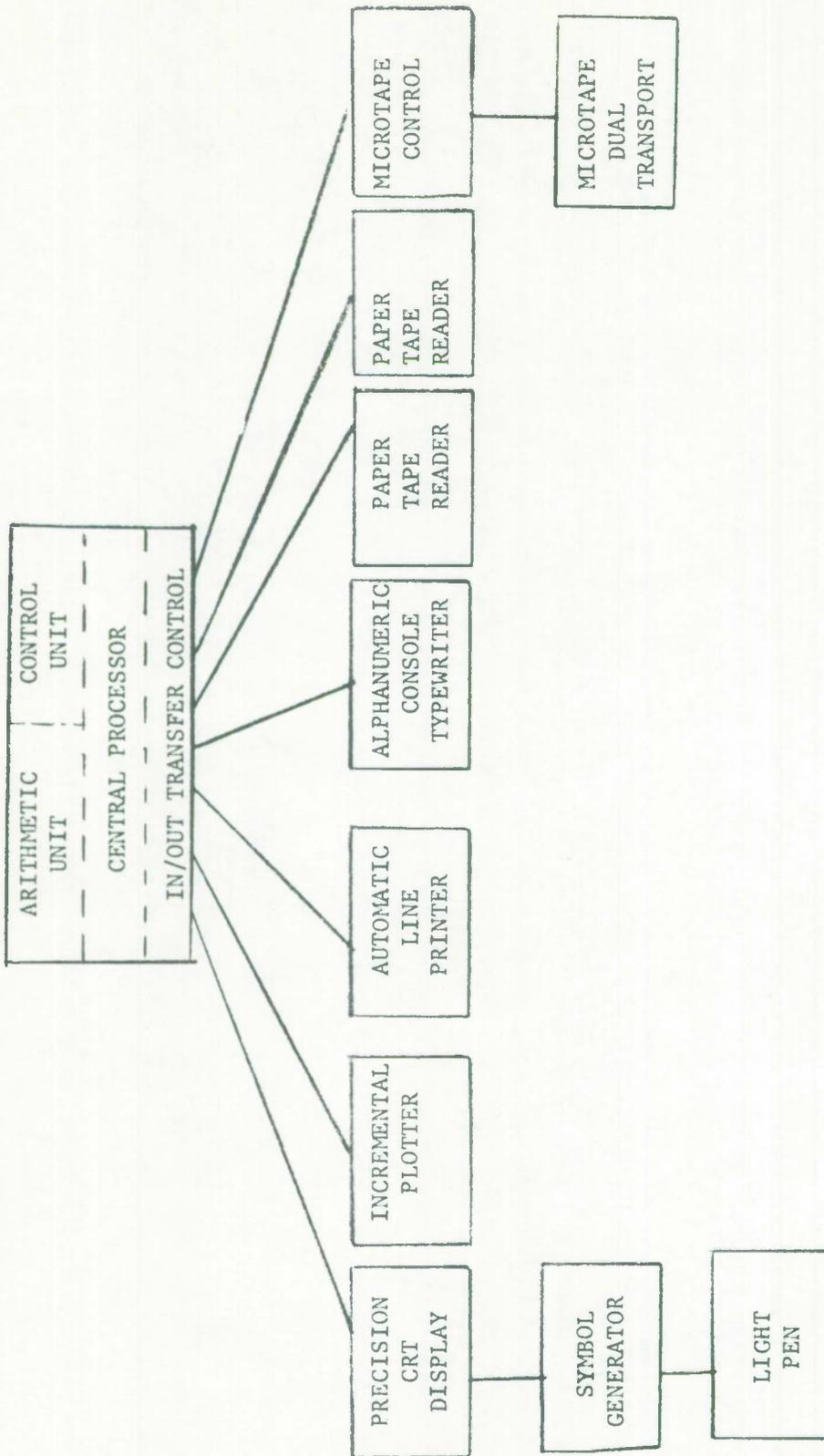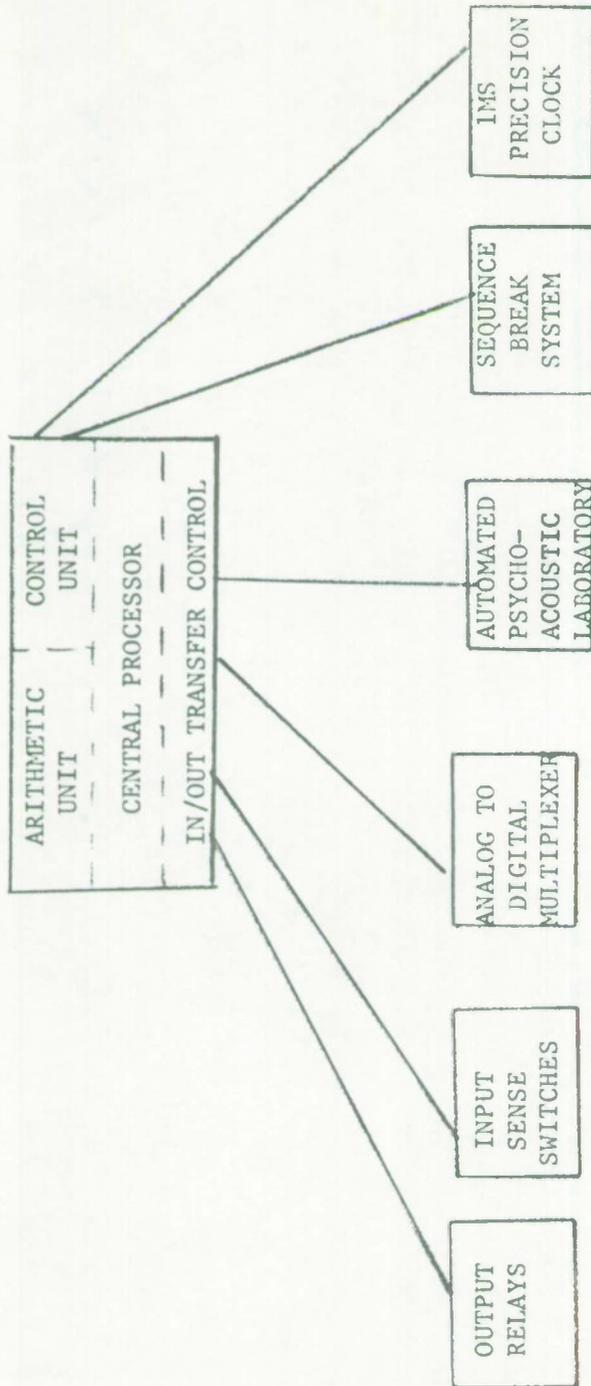
REAL–TIME EQUIPMENT CONTROL GROUP
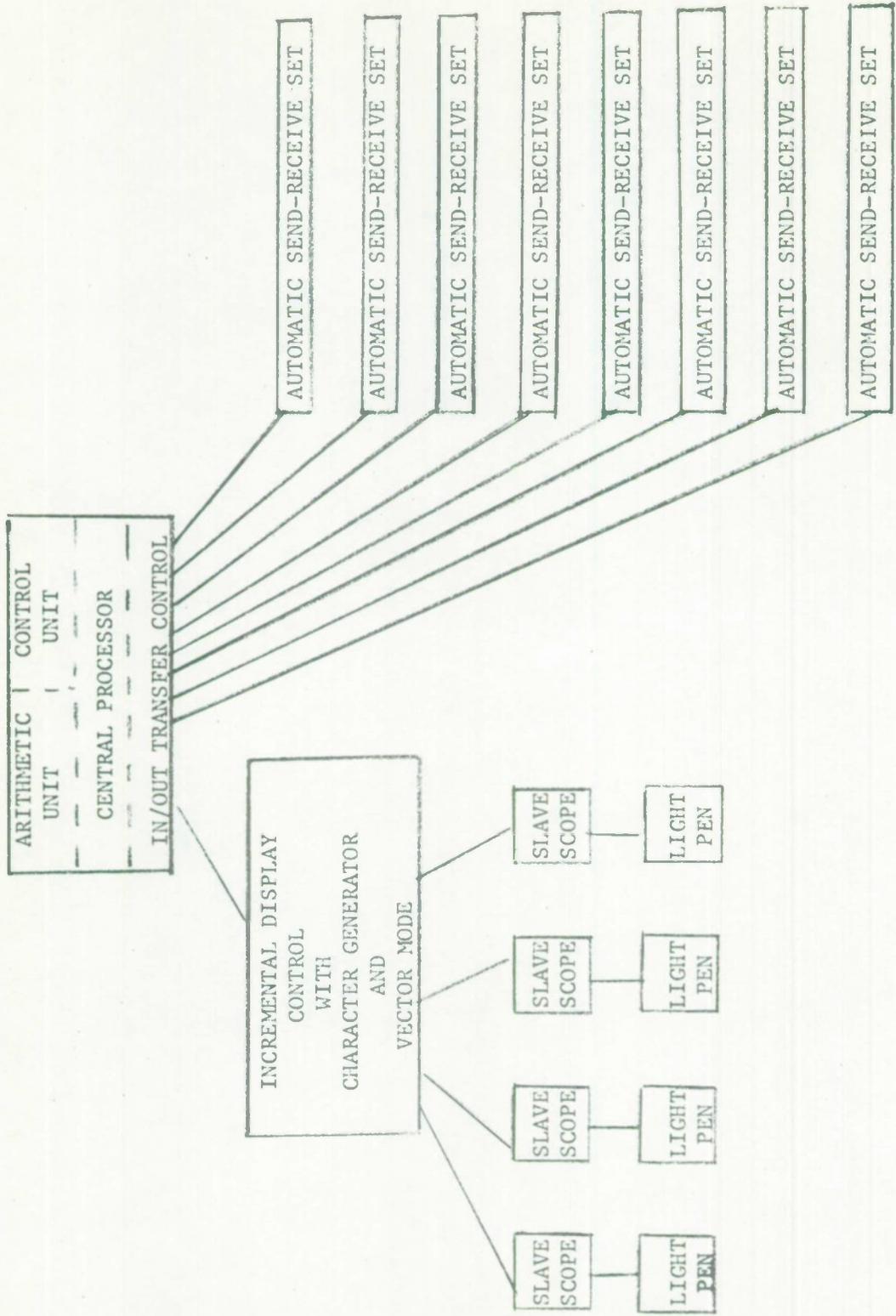
EXPERIMENTAL USER STATION GROUP

APPENDIX II

This appendix contains descriptions of the items of equipment at the Decision Sciences Laboratory computer facility.

A. CENTRAL PROCESSOR

   1. DEC PDP-1 Computer

      a. General System

Application	General purpose
Timing	Synchronous
Operation	Parallel processing

      b. Computer Words

Word length	18 bits
Number length	Sign: 1 bit; Magnitude: 17 bits
Instruction length	
Memory reference	Operation code: 6 bits including an indirect address bit: Address: 12 bits
Augmented	Variable operation code; maximum length: 18 bits
Instruction type	Single address

      c. Arithmetic Unit

Internal number system	Binary
Operation	Fixed point
Number range	$-(1 - 2^{-17}) = n = (1 - 2^{-17})$
Addition time	10 microseconds
Multiplication by subroutine	352 microseconds
Division by Subroutine	440 microseconds
Multiplication by option	14 to 24 microseconds
Division by option	30 to 40 microseconds (if division is not possible, 12 microseconds)

      d. Storage

Media	Magnetic cores
Cycle time	5 microseconds
Capacity	4,096 words, expandable to 65,536 words

B. CORE MEMORY GROUP

    1. <u>Memory Extension Control, DEC Type 15</u> - The PDP-1 memory may be expanded to sixteen type 12 memory modules by installing a memory extension control. This expanded memory provides storage for 65, 536 18-bit words. The 16-bit address format necessary to address 65, 536 (=2^{16}) memory locations, is provided by extending both the program counter and the memory address register from 12 to 16 bits. The 4-bit address extension then selects the module while the regular 12-bit address specifies a single location in the selected module. In normal operation, instructions and operands are retrieved from a single module. However, the program may jump to another module, or retrieve and operand from another module, by performing an extend-mode cycle. In an extend-mode cycle, instead of being interpreted as a 12-bit address it is interpreted as a 16-bit address.

    2. <u>Memory Module, DEC Type 170D</u>

        a. <u>Capacity</u> - 4096 words each, 24,576 words total

        b. <u>Word Size</u> - 18 bits

        c. <u>Access</u> - random access to any word

        d. <u>Speed</u> - read-write cycle time per word to be 5 microseconds with all 18 bits per word being parallel processed.

        e. <u>Mounting</u> - one key cabinet on casters for the above additional equipment and fastened to existing computer.

        f. <u>Cabinet Size</u> - 22-1/4"W. x 27-1/16"D. x 69-1/8"H.

        g. <u>Finish</u> - blue and light grey with dark grey trim to match present Digital Equipment Corporation equipment.

        h. <u>Weight</u> - 350 lbs or less

        i. <u>Power</u> - 117V 60 cycle AC at 3 Amps maximum.

        j. <u>Temperature</u> - to function properly in normal room conditions and over range 50° to 90° F.

C. MASS MEMORY GROUP

    1. <u>Drum Data Storage, DEC Type 24G/131</u>

        a. <u>24G Serial Drum</u>

        <u>Storage Size</u> - 131,072 19-bit words
        <u>Block Length</u> - 512 words fixed, or variable to 4096 (optional)

Bits per word - 18 + 1 parity
Word Transfer Rate - 66 microseconds/word
Block Transfer Rate - 34.6 milliseconds (512 words)
Instructions - 2 instructions cause the transfer of a 512
word block. Computations continue during block transfers,
(necessary instructions for operation with PDP-1)
Registers - 4 in control unit
Drum speed - 1800 rpm
Power - 115 volt/60 cycles, simple phase, 8 ampere starting
current, 5 amperes running.
Signal cables - two
Weight - 550 pounds (approx.)

b. Type 131 Data Channel

Description: Transfers data blocks between PDP-1 Computer
and up to 3 external devices. Transfers are made from consecutive
memory locations to one device at a time.

Maximum Trafsfer rate - 5 microseconds
Transfers from PDP-1 - through a Type 19 High Speed Channel
Registers: (in control unit) (not all displayed)
            buffer 1
            buffer 2
            device register
            location counter
            word counter
Instructions - Set word count
            Set initial location
            Stop data flow
            Examine location counter
Power - 115 volt, 60 cycle
Size - 1 standard DEC bay

2. Automatic Tape Control, DEC Type 52

   a. Capacity - can control up to 8 DEC Type 50 Magnetic Tape
Transports so as to automatically effect transfers of information between
the Digital Equipment Corporation (DEC) Model PDP-1 Computer (already
installed) and the tape in variable length blocks of characters.

   b. Non-Interruption - permits computation by the computer
while transfer is in process by using a high-speed channel control in
conjunction with a special data channel.

   c. Skip - skips pre-selected number of blocks while searching for
greater speed.

   d. Format - standard IBM and also compatible with that of the DEC
Type 50 Transport.

- 28 -

e. Registers - 9 major: data word buffer (18 bit); read buffer (7 bit); final address register (16 bit); current address register (16 bit); command register (4 bit); tape unit register (3 bit); stop-continue register (2 bit).

f. Instructions - provide 8 additional instructions to the present DEC PDP-1 Computer to function with this item:

        (1) Magnetic Tape Unit and Final (5 msec)
        (2) Magnetic Tape Initial and Command (5 msec)
        (3) Magnetic Tape Reset Final (5 msec)
        (4) Magnetic Tape Reset Initial (5 msec)
        (5) Magnetic Tape Examines States (5 msec)
        (6) Magnetic Tape Examines Location (5 msec)
        (7) Initiate a High-Speed Channel Request (5 msec)
        (8) Clear Command Register (5 msec)

g. Power - 117V, 60 cycle, AC

3. Magnetic Tape Transport, DEC Type 50

a. Recording Density - 200 7-bit character per inch, inter-record gap of 3/4 inch and interfile gap of 3-1/2 inches.

b. Speed - 75 inches per second for read-write to provide a 15,000 character per second transfer rate; rewind speed 225 inches per sec.

c. Method - non-return to zero.

d. Tape - Magnetic 1/2" wide on 10-1/2" diam. reels NARTB both feed and take-up.

e. Size - 5' 9-1/8" high by 22-1/4" wide by 2' 3" deep in floor cabinet with doors.

f. Start - Stop - 3 milliseconds start and 1.5 milliseconds stop time, maximum.

g. Flutter - 3% max. at running speed

h. Weight - 620 lbs or less

i. Logic - as required so that proper operation is obtained from present DEC Type 50 Tape Transport so that the present DEC Type PDP-1 Computer can control and function with both transport.

j. Power - 115V, 60 cycle, single phase, AC

- 29 -

D.   PROGRAM AND DATA INPUT-OUTPUT GROUP

1.   Precision CRT Display, DEC Type 30 - The Type 30 Precision CRT
Display is an ancillary equipment designed to be used with digital computers.
It is a random-position, point-plotting cathode ray tube with power
supplies mounted in a table. The equipment receives X and Y coordinate
information, and, on command, displays a spot of light on the screen of
a cathode ray tube at this translated position. Discrete points may be
plotted in any sequence at a 20 kilocycle rate (one point every 50 microseconds).
Provision is made for a Light Pen to be used for identification and selection
of any specify display area. The Type 30 Precision CRT Display consists of
a 16-inch cathode ray tube in an adjustable mounting and a table with all
the electronic equipment mounted beneath it.

2.   Symbol Generator, DEC Type 33

a. Compatibility to operate from information and commands for a
Digital Equipment Corporation Model PDP-1 computer and to cause appropriate
symbol displays on an associated Digital Equipment Corporation Type 30
Cathode Ray Tube Display.

b. Symbols - each consists of a maximum of 35 dots in a 5 x 7 dot
matrix, any configuration therein.

c. Size - 4 sizes of 5 x 7 dot matrices available under program
control. In the smallest size, the space between adjacent dots to be
the same as the space between alternating dots in a line consisting of 1024
dots on the present display. The other 3 matrix sizes shall be 3/2, 4/2 and
5/2 or large as the smallest size.

d. Size Control - size of matrix under program control from contents
of bits 16 and 16 of the IO register.

e. Symbol Control - symbol to be displayed is determined by two
18 bit words from the computer.

f. Instructions - The computer recognizes and executes the following
commands: generator plot (to initiate plot of up to 35 dots); load format
(to determine matrix size); space (to position the display one symbol position
to the right); load buffer - intensify; load buffer - no intensity.

g. Flicker- up to 220 characters or symbols (averaging 16 dots each)
may be displayed without noticeable flicker.

3. Light Pen, DEC Type 32 - The Light Pen is designed to be used with
the CRT Display Type 30. By "writing" on the face of the CRT, stored or
displayed information can be expanded, deleted or modified. Specifically,
each time a light-pulse strikes the pen, the Light Pen status bit is set to
one and Program Flag 3 is set to one.

4. Incremental Plotter, Calcomp Model 565 with Interface

   a. Plotting Speed - 18000 steps/min., X axis;
                        18000 steps/min., Y axis;
                          600 oper./min., pen up-down

   b. Step Size - 0.01 inch

   c. Plotter Weight - approximately 33 lbs.

   d. Plotter Size - 9-3/4 H. x 18" W. x 14-3/4" D. for table mounting

   e. Chart Paper - 12 W. with 11 plotting width; 120' roll.

   f. Power - to operate from nominal 117V 60 cycle AC and draw
approximately 1.5 Amps.

   g. Commands - provide IOT commands as required

   h. Cable - provide connector and approximately 50' of cable to
connect plotter to computer.

   i. Modules - interface modules shall be located in present computer
in space available.

   j. Temperature - to function properly in normal room condition and
over range 50° to 90° F.

5. Automatic Line Printer and Control, DEC Type 65

   a. Compatibility - functions with present type PDP-1 Computer.

   b. Speed - 300 lines per minute.

   c. Capacity - can print up to 120 standard size characters per line
with any of 64 characters in each position.

   d. Spacing - eight possible spacings under computer control.

   e. Instructions - provide IOT instructions in present computer to:
(a) Clear Buffer, (b) Load Printer Buffer, (c) Print and Space.

   f. Cables - provide cable and connectors so printer can be up to 25'
from computer.

   g. Power - 115V AC, 60 cycles, 6 amperes max. surge.

   h. Temp. - functions up to at least 122° F. ambient.

- 31 -

i. <u>Size</u> - 48" H. x 41" W. x 20" D. overall cabinet.

j. <u>Weight</u> - 800 lbs.

k. <u>Loading</u> - provides 4 casters positioned so that floor loading is not more than 141 lb/ft^2.

l. <u>Finish</u> - blue and grey to match present computer.

6. <u>Alphanumeric Console Typewriter</u> - A modified standard IBM electric typewriter is provided as an in-out device for the operator.

7. <u>Paper Tape Reader</u> - The perforated Tape Reader of the PDP-1 is a photoelectric device capable of reading 400 lines per second. Three lines form the standard 18-bit word when reading binary punched eight-hole tape. Five, six, and seven-hole tape may also be read.

8. <u>Paper Tape Punch</u> - The standard PDP-1 perforated Tape Punch operates at a speed of 63 lines per second. It can operate in either the alphanumeric mode or the binary mode.

9. <u>Microtape Control, DEC Type 550</u>

a. <u>Information Registers</u> - (1) 18-bit Read/Write serial-parallel register; (1) 18-bit In/Out register which transfers in parallel format to the present DEC PDP-1 computer and also to the Read/Write register; (1) 7-bit Mark Track Recognition register plus (6) 6-bit mark detection gates.

b. <u>Control Registers</u> - one (1) 6-bit mode buffer for Search, Read, Write and Move commands; (1) 3-bit Unit Selection register

c. <u>Capacity</u> - controls up to (4) DEC Type555 Dual Tape Transports

d. <u>Compatibility</u> - functions properly with the present DEC Model PDP-1 Computer

e. <u>Information Transfer</u> - to and from computer either word by word or in blocks using sub-routines

f. <u>Assembly</u> - format is 18-bit words to and from the computer and 3-bit words to and from the controlled tape transport.

g. <u>Error Detection</u> - by programmed check sum.

h. <u>Flags</u> - to indicate error, block, data

i. <u>Control Tracks</u> - the timing and mark tracks appearing on the tape are generated by this unit by means of a computer program.

- 32 -

j. Block Length - 256 words plus 2 check sum words.

k. Size - 20"W. x 27"D. x 70"H.

l. Weight - 50 lbs.

m. Power - 117 volts 60 cycles AC

10. Microtape Dual Transport, DEC Type 555

a. Recording Density - 350 3-bit characters per track inch

b. Tracks - 3 pairs, each pair recorded from same channel but are not adjacent.

c. Reel Size - 3-1/2 inch diameter for 250 feet of 3/4 inch tape (1 mil mylar)

d. Speed - 70-85 inches per second; 42 seconds to read or write a complete reel.

e. Transfer Rate - 80,000 bits per second; a standard block of 256 18-bit words transferrable in 53 milliseconds.

f. Method - phase shift recording with permanent dual timing track and dual block mark track

g. Acceleration - 700 ± 150 l.p.s.

h. Accel. Dist. - 8 inches max.

i. Controls - Rev. Forw. Switch; Write-Off switch, for each of the two transports.

j. Compatibility - functions properly with the DEC Type 550 Tape Control and with the present DEC Model PDP-1 Computer in this organization.

k. Direction - search possible in either direction.

l. Power - 117 volt 60 cycle AC

m. Weight - 60 lbs.

n. Size - 20" L x 12" H. x 13" D.

E. REAL-TIME EQUIPMENT CONTROL GROUP

   1. Output Relays, Input Sense Switches, and One Millisecond Clock

       a. 18-bit capacity for Relay Buffer and Switch Status Read-in.

       b. mercury type relays with SPDT contacts for each of the 18 bits
of the buffer.

       c. relay operate time 4 millisecond or less.

       d. relay contacts rated at 2 amperes non-inductive load.

       e. contacts of each relay wired to front of panel miniature patching
jacks.

       f. 1 kc crystal-controlled clock will permit measuring the time
intervals between operations of bits 0 thru 16 of the Relay Buffer and
operations of switches connected to the Switch Status Read-in.

   2. Sequence Break System, DEC Type 20 - This automatic interrupt feature
allows concurrent operation of several in-out devices and the main sequence.
The system has 16 automatic interrupt channels arranged in a priority chain.
An interrupt or break can be initiated by an in-out device at any time.
When a break occurs, the computer stores in several fixed memory locations
all information necessary for a later return to the main program. Program
control is then transferred to a routine which serves the device causing
the interrupt.

   3. Analog to Digital Convertor and Multiplexer, Adage Model VMX-10/VR10AB

       a. A to D converter portion

          (1) Bits: 11 (logical 1's complement)

          (2) Rate: 16,666 max. conversions per second for external
trigger each conversion consisting of 11 bits as above.

          (3) Resolution: 0.05% of full scale $\pm$ 1/2 least significant bit.

          (4) Trigger modes: switch selected: external, internal (approx.
3,500 ops) and line frequency.

          (5) Ambiguity: if input level varies during conversion period,
output is an actual value that occurred during the conversion period.

          (6) Input: input levels to be converted can have any magnitude
between, respectively, -1 to +1, -10 to +10 and -100 to +100 volts in three
switch-selected ranges representing full scale.

          (7) Trigger levels: external start trigger level approx. 2.5 volts
negative with duration of at least 0.4 microsecond and external reset trigger
level 2.5 volts negative so as to be compatible with Digital Equipment Corp.
type PDP-1 computer.

- 34 -

(8) <u>Output coding:</u> pure binary with logical 0 equalling 0 volts, logical 1 equalling -3 volts and also separately available the complements of these. These levels must be adequate to operate into a Digital Equipment Corp. Model PDP-1 computer.

(9) <u>Display:</u> For each bit individual miniature lamp when lit to indicate a logical one. Located on front panel.

(10) <u>End of conversion:</u> Provide an output going from 0 voltage level to -3 voltage level at the end of conversion.

      b. <u>Multiplexer Portion</u>

(1) <u>Channels:</u> 10

(2) <u>Full Scale Input Voltage:</u> 10 volts, bipolar

(3) <u>Current Sensitivity:</u> 0.1 MA full scale

(4) <u>Non-linearity:</u> Plus or minus 0.005 percent, max.

(5) <u>Interchannel Offset Spread:</u> Plus or minus 0.017 percent, max.

(6) <u>Interchannel Gain Spread:</u> Plus or minus 0.015 percent, max.

(7) <u>Drift Stability, Offset:</u> Plus or minus 0.1 percent, max.

(8) <u>Drift Stability, Gain:</u> Plus or minus 0.025 percent, max.

(9) <u>Crosstalk:</u> Negligible up to 300% overload.

(10) <u>Speed:</u> At least 50,000 samples per second at max. rate.

(11) <u>Input impedence:</u> Constant 100,000 ohms resistive.

(12) <u>Display:</u> Miniature lamp to indicate when each channel is on.

(13) <u>Switching Mode:</u> Panel switch to select either manual or external random.

(14) <u>Expandability:</u> expandable to 20 channels with plug-in modules.

(15) <u>Output:</u> 5 volts for full scale input voltage when delivering 10 Ma.

(16) <u>External Random Addressing:</u> parallel 0 and -3 volt level inputs consisting of: 8-4-2-1 Binary Coded Decimal and a -2.5 volt, 0.4 microsecond pulse to sample these four input lines. In addition, provide a "clear" input line suitable for a -2.5 volt 0.4 microsecond pulse.

(17) Channel indication: Parallel static voltage levels indicating contents of address register in 8-4-2-1 Binary Coded Decimal with complement. Logic levels of +2.5 and -2.5 volts.

(18) End Scan Channel: any channel can be selected to be the last channel connected when scanning sequentially after which the multiplexer will return to the "0" channel.

c. Common Features

(1) A to D converter and multiplexer in one integrated unit and inter-connected.

(2) Size: 5-1/4" high x 19" wide for standard rack mounting.

(3) Circuitry: All circuits transistorized.

(4) Environment: in standard rack cabinet with other low heat equipment in air-conditioned room of less than 26°C, but usable over range 0° to 45°C.

(5) Weight: 60 lb or less.

(6) Power: From 105 to 125 volts AC, 50 to 1000 cycles per second, 80 watts or less.

4. Automated Psycho-acoustic Laboratory Control - This control permits the PDP-1 to calibrate and interconnect equipment of audio-bandwidth. A computer controlled knob-twisted permits dial settings to be varied during an experiment. Thus, standard laboratory equipment may be placed under computer control. A problem oriented language reduces the time required to set up an experiment. Equipment such as oscillators and attenuators may be continuously modified as a function of an observers judgments.

F. EXPERIMENTAL USER STATION GROUP

1. Incremental Display Control, DEC Type 340

a. Plotting Modes

(1) Control words (random)
(2) Incremental
(3) Vector
(4) Character

b. Input - Connections to Type 131 Data Channel to allow high speed data transfers.

- 36 -

c. <u>Function</u> - Decode data words to initiate mode of operation and allow display data (eight data input or generated data) to be transferred through a slave scope selector to a slave.

d. <u>Slave Scope Selector</u> - Permits individual operation of slave scopes and light pens.

e. <u>General Specifications</u>

(1) <u>Random Mode</u>

(a) Display time - 35 microseconds minimum

(2) <u>Incremental Mode</u>

(a) Display time - 1.5 microseconds minimum
(b) Format - 1 control word will cause 4 successive points to be plotted.
(c) Mode - Escape bit capabilities

(3) <u>Vector Mode</u>

(a) Display time - 1.5 microseconds minimum
(b) Format - 8 bits of Δx, 8 bits of Δy, intensity bit and escape bit.
(c) A single instruction can display $\pm$ 1/8 raster size (max.)

(4) <u>Character Mode</u>

(a) Format - 6 bit code, 3 codes/word
(b) Standard character alphabet available (including case shift, space, carriage return)
(c) Escape bit capabilities
(d) Approx. character plotting time = 30 microseconds (avg) (matrix plot)

(5) <u>Size</u> - 1 standard DEC Bay

(6) Connections to Type 343 slave - cables.

2. <u>Type 341 Vector Mode</u> - Displays a straight line between 2 points without specifying in-between points.

a. <u>Data Format</u> - 8 bits - delta X, 8 bits delta Y, intensity bit and escape bit. Delta X and delta Y comprise 7 magnitude and 1 direction bit.

b. <u>Maximum length Vector</u> - $\pm$ 1/8 raster size (1024x1024 raster)

c. <u>Minimum length Vector</u> - no limitation

d. <u>Plotting speed</u> - 1.5 microseconds/point.

- 37 -

3. Character Generator, DEC Type 342 - Provisions for modular inclusion in Type 340.

    a. Symbol Code - 6 bits

    b. Data Format - 3 symbol codes of 6 bits each

    c. Characters - provisions for 128 character alphabet including case shift, space, and carriage return.

    d. Character Speed - approx. 30 microseconds (average)

    e. Compatibility - to operate from information and commands from a Digital Equipment Corporation Model PDP-1 computer and to cause appropriate symbol displays on an associated Digital Equipment Corporation Type 343 Cathode Ray Tube Slave Display.

    f. Symbols - each consists of a maximum of 35 dots in a 5 x 7 dot matrix, any configuration therein.

    g. Size - 4 sizes of 5 x 7 dot matrices available under program control. In the smallest size, the space between adjacent dots to be the same as the space between alternating dots in a line consisting of 1024 dots on the present display.

4. Slave Scope, DEC Type 343

    a. General Description

        (1) CRT slave for Type 340 display
        (2) Deflection system - magnetic
        (3) CRT size - 16" (16 ADP7A)
        (4) Raster Size - 9-3/8" x 9-3/8" (1024x1024 points)
        (5) Pincushion Distortion - less than 3/16" per side
        (6) Focus - magnetic
        (7) Stability - +0.5% raster size (point)
                       +0.5% raster size (deflection system)
        (8) Accuracy - +3% raster size overall, +1% raster size, not including distortion due to geometry of deflecting system and yoke.
        (9) Housing - 1 standard DEC bay with operators table attached.
        (10) Selection Capabilities - Intensity selection through control signals from Type 340 Control.

    b. The Type 343 Precision CRT Slave Display is an ancillary equipment designed to be used with digital computers. It is a random-position, point-plotting cathode ray tube. The equipment receives X and Y coordinate information, and, on command, displays a spot of light on the screen of a cathode ray tube at this translated position. Discrete points may be plotted in any sequence at a 20 kilocycle rate (one point every 50 microseconds). Provision is made for a Light Pen to be used for identification and selection of any specific display area.

5. Light Pen, DEC Type 370

    a. General Description: Photo multiplier tube, power supply amplifier and flexible light pipe. (Mounted in CRT housing)

        (1) Shutter - mechanical (mounted in holder)
        (2) Speed - 50 μ sec/point (P7 phosphor)
        (3) Gain Control - mounted on CRT housing

    b. The Light Pen is designed to be used with the CRT Slave Display Type 343. By "writing" on the face of the CRT, stored or displayed information can be expanded, deleted or modified. Specifically, each time a light-pulse strikes the pen, the Light Pen status bit is set to one and Program Flag 3 is set to one.

6. Automatic Send-Receive Set, Teletype Model 33

    a. General - The ASR set is used to originate the transmission of messages by either the manual operation of a keyboard or the reading of perforated paper tape. Messages may be recorded at the machine, whether originated at the machine or remotely, by perforating paper tape and/or printing onto page-width copy paper. The basic components are: (1) a printer consisting of a 4 row keyboard, a printer assembly, a motor, a sub-base, a cover; (2) a tape reader; (3) a tape punch. Printer paper is to feed from a roll at the rear and is led around a platen where it is printed. A window permits viewing the printed copy. The tape punch and tape reader are mounted on the left side of the set. The tape feeds forward from a roll into the punch where it is perforated. Provides a removable container for collecting chad from the punch.

    b. Printer

        (1) motor - single-phase 115 V.A.C., 3600 RPM, 0.033 H.P.

        (2) Keyboard - consisting of a space-bar and keys similar to those of a typewriter, a code bar mechanism which converts the manual depression of the keys to mechanical positions corresponding to the proper code combinations, a contact mechanism in which the code bar mechanism sets up the code combinations for transmission, a frame with brackets and cover, cable and connector. Has four rows of keys and generates an 8 level code of standard teletype format.

        (3) assembly - principal components include: (1) a main shaft receiving motion from the drive parts and distributes it to the various mechanisms; (2) a selector mechanism which translates the signals to corresponding mechanical arrangements that control a code bar mechanism; (3) a code bar mechanism which controls printing, functions and tape punching; (4) a printing carriage having a cylindrical type wheel on which characters are embossed. Accepts paper 8-1/2" wide. Prints 74 char/line; (5) a

function mechanism to accomplish the functions of space, carriage return, line feed, blank, bell; (6) a paper feed mechansim for single or double line feed with knot for manual feed; (7) a spacing mechanism for positioning the carriage. Carriage return to have a dash-pot cylinder for shock-less operation. (8) a distributor mechanism for converting the positions of the keyboard contacts to signals for transmission; (9) answer-back mechanism which may be coded to transmit any sequence of up to 20 characters and may be actuated locally or remotely.

(4) cover & sub-base - provide plastic decorative and protective enclosure for the printer and keyboard assemblies. Provide lid for access to permit replenishing paper and ribbon. Mount cover over a cast sub-base serving as foundation for the key-board, printer assembly and call-control assembly. Printer is to be supported on shock-mounts.

(5) size & weight 22" w. x 8-3/8" H. x 18-1/2" D: 44 lbs.

c. Stand

(1) purpose - to support the printer, punch and reader at a convenient operating height and to permit housing of auxiliary equipment. Provide removable rear panel and feet having levelling screws.

(2) size - 17-3/4" w. x 24-1/2" h. x 17-3/4" overall

(3) weight - 12 lbs.

d. Tape Reader

(1) tape - 8 hole 1" wide, 10 lines/inch

(2) speed - 10 lines per second

(3) power supply - for feed magnet; locate in enclosure part of stand 115VAC operation, 6-1/4" w. x 2-1/2" d. x 2-3/4" h. 1b.

(4) auto. stop - provide automatic stop of reader if it runs out of tape or if tape is too taut.

e. Tape Punch

(1) tape - 8 hole, 1" wide, 10 lines/inch

(2) speed - 10 lines per second

(3) supply - provide supply reel for blank tape

(4) controls - 4 push-buttons to (1) turn on; (2) turn off; (3) release feed and guides for manual handling; (4) back-space.

f. size & wt. - 3-1/2" w. x 7-1/2" h. x 13-1/4" d.; 1-1/2 lbs.

DOCUMENT CONTROL DATA - R&D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author)	2a. REPORT SECURITY CLASSIFICATION
Decision Sciences Laboratory, Electronic Systems Division, L.G. Hanscom Field, Bedford, Massachusetts	Unclassified
	2b. GROUP n/a

3. REPORT TITLE

The Decision Sciences Laboratory Program of Techniques and Facilities for Automating Research.

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)

In-house, September 1964

5. AUTHOR(S) (Last name, first name, initial)

Shuford, Emir H., Jr.

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
September 1964	43	0

8a. CONTRACT OR GRANT NO. None	9a. ORIGINATOR'S REPORT NUMBER(S)
b. PROJECT NO. 4690	ESD-TDR-64-553
c.	9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)
d.	None

10. AVAILABILITY/LIMITATION NOTICES

Qualified requesters may obtain from DDC.
May be made available to the Office of Technical Services, Department of Commerce

11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY
None	Electronic Systems Division, Air Force Systems Command, L.G. Hanscom Field, Bedford, Mass., 01731

13. ABSTRACT

This is a report on the application of techniques and the use of computer facilities in automating research in the Decision Sciences Laboratory. Applications are divided into six categories; (1) real time control of experimental tasks performed by human subjects, (2) statistical analysis of experimental data, (3) stimulation and sensitivity analyses, (4) studies in information retrieval, (5) techniques for improving the man/computer interface, and (6) computer-based personnel selection, classification, training, and proficiency testing. Examples are given of each application.

There is also included detailed facility lay-out and description of equipment characteristics.

DD FORM 1 JAN 64 **1473**

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Decision Making Behavior Experimental Data Programming (Computers) Analysis Information Retrieval Man-Machine Interaction Laboratory Facility Automated Experimentation						

INSTRUCTIONS

1. ORIGINATING ACTIVITY: Enter the name and address of the contractor, subcontractor, grantee, Department of Defense activity or other organization (corporate author) issuing the report.

2a. REPORT SECURITY CLASSIFICATION: Enter the overall security classification of the report. Indicate whether "Restricted Data" is included. Marking is to be in accordance with appropriate security regulations.

2b. GROUP: Automatic downgrading is specified in DoD Directive 5200.10 and Armed Forces Industrial Manual. Enter the group number. Also, when applicable, show that optional markings have been used for Group 3 and Group 4 as authorized.

3. REPORT TITLE: Enter the complete report title in all capital letters. Titles in all cases should be unclassified. If a meaningful title cannot be selected without classification, show title classification in all capitals in parenthesis immediately following the title.

4. DESCRIPTIVE NOTES: If appropriate, enter the type of report, e.g., interim, progress, summary, annual, or final. Give the inclusive dates when a specific reporting period is covered.

5. AUTHOR(S): Enter the name(s) of author(s) as shown on or in the report. Enter last name, first name, middle initial. If military, show rank and branch of service. The name of the principal author is an absolute minimum requirement.

6. REPORT DATE: Enter the date of the report as day, month, year; or month, year. If more than one date appears on the report, use date of publication.

7a. TOTAL NUMBER OF PAGES: The total page count should follow normal pagination procedures, i.e., enter the number of pages containing information.

7b. NUMBER OF REFERENCES: Enter the total number of references cited in the report.

8a. CONTRACT OR GRANT NUMBER: If appropriate, enter the applicable number of the contract or grant under which the report was written.

8b, 8c, & 8d. PROJECT NUMBER: Enter the appropriate military department identification, such as project number, subproject number, system numbers, task number, etc.

9a. ORIGINATOR'S REPORT NUMBER(S): Enter the official report number by which the document will be identified and controlled by the originating activity. This number must be unique to this report.

9b. OTHER REPORT NUMBER(S): If the report has been assigned any other report numbers (either by the originator or by the sponsor), also enter this number(s).

10. AVAILABILITY/LIMITATION NOTICES: Enter any limitations on further dissemination of the report, other than those

imposed by security classification, using standard statements such as:

(1) "Qualified requesters may obtain copies of this report from DDC."

(2) "Foreign announcement and dissemination of this report by DDC is not authorized."

(3) "U. S. Government agencies may obtain copies of this report directly from DDC. Other qualified DDC users shall request through
_____ ."

(4) "U. S. military agencies may obtain copies of this report directly from DDC. Other qualified users shall request through
_____ ."

(5) "All distribution of this report is controlled. Qualified DDC users shall request through
_____ ."

If the report has been furnished to the Office of Technical Services, Department of Commerce, for sale to the public, indicate this fact and enter the price, if known.

11. SUPPLEMENTARY NOTES: Use for additional explanatory notes.

12. SPONSORING MILITARY ACTIVITY: Enter the name of the departmental project office or laboratory sponsoring (paying for) the research and development. Include address.

13. ABSTRACT: Enter an abstract giving a brief and factual summary of the document indicative of the report, even though it may also appear elsewhere in the body of the technical report. If additional space is required, a continuation sheet shall be attached.

It is highly desirable that the abstract of classified reports be unclassified. Each paragraph of the abstract shall end with an indication of the military security classification of the information in the paragraph, represented as (TS), (S), (C), or (U)

There is no limitation on the length of the abstract. However, the suggested length is from 150 to 225 words.

14. KEY WORDS: Key words are technically meaningful terms or short phrases that characterize a report and may be used as index entries for cataloging the report. Key words must be selected so that no security classification is required. Identifiers, such as equipment model designation, trade name, military project code name, geographic location, may be used as key words but will be followed by an indication of technical context. The assignment of links, rules, and weights is optional